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Design and Fabrication of a Large Vertical Travel Silicon Inchworm Microactuator for Advanced Segmented Silicon Space Telescope (ASSiST)

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Novelty: A MEMS-based vertically actuated inchworm microactuator is proposed to perform a large travel, precision step motion. This inchworm technology can be achieved by utilizing the piezoelectric-driving and electrostatic-clamping actuations of silicon microstructures comprised of a silicon structure with polymer beams.

Background, Design and Fabrication: The goal of this research is to develop inchworm motor systems capable of simultaneously providing nanometer resolution, high stiffness, large output force, long travel range, and compactness for ultraprecision positioning applications in space. Since conventional inchworm actuator technologies are bulky, there are huge demands for the development of miniaturized inchworm motors (or actuators). There are a few MEMS-based inchworm actuators previously reported, without large travel actuation (~ hundreds microns), nanometer-scale precision, or vertical actuation [1-4].

A MEMS-based vertical inchworm microactuator is proposed to achieve a large travel actuation with a nanometer-scale step motion by using compliant polymer beams and precision silicon micromachining of a thick (~ hundreds microns) silicon wafer. The inchworm actuator motion can be created through sequential activation of actuation elements as shown in Fig. 1. The designed specification of the actuator is as follows.

• Operation up to 1 kHz (but this bandwidth is not likely required)
• 77K or lower operation possible, with reduced stroke (15-20% room temperature stroke)
• 250 mm total travel with nm precision
• Electrostatic holding force between segments ~ 2 N (@ 100V)
• Mean steady-state power goal for 72,000 actuators is 7.2 W (100 mW each)

An inchworm actuator unit consists of a piezoelectric stack actuator, a driver, a pair of holders, a slider, and a pair of polymer beams connected with a centrally-clamped flexure beam as shown in Fig. 2. Fig. 3 shows SEM photographs of the fabricated silicon structure.

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References

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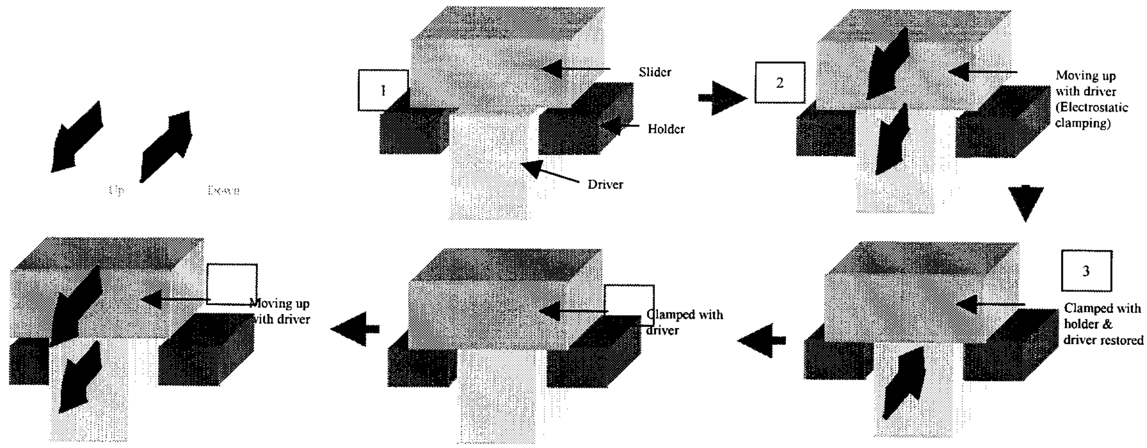

Fig. 1 The simplified actuation sequence of the inchworm actuation. 1-2) The slider is electrostatically clamped to the driver. The driver is moving upward by the piezoelectric stack actuator directly connected to the bottom of the driver. 3) The slider is then clamped with the holders. Then the slider is subsequently released from the driver. The separated driver is moving downward by the piezoelectric actuator, while the slider is clamped to the fixed holders. 4) The slider is clamped again to the driver when the slider is still clamped to the holders. The slider is released from the holders. 5) The slider is moved upward with the driver, since it is clamped to the driver in the step 4. The inchworm actuation is achieved by repeating these steps (step 2-4).

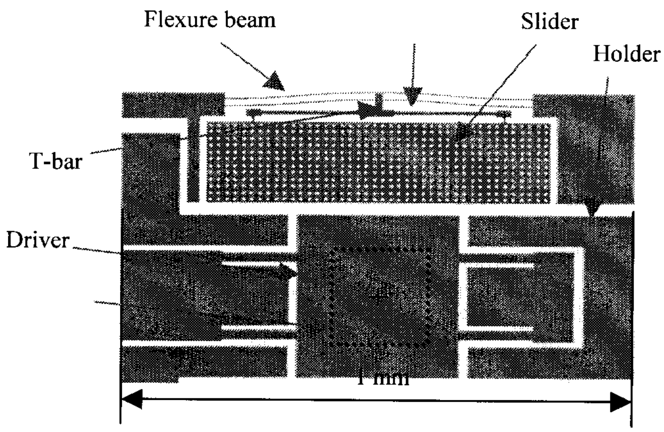

Fig. 2 The top view of the actuator layout.

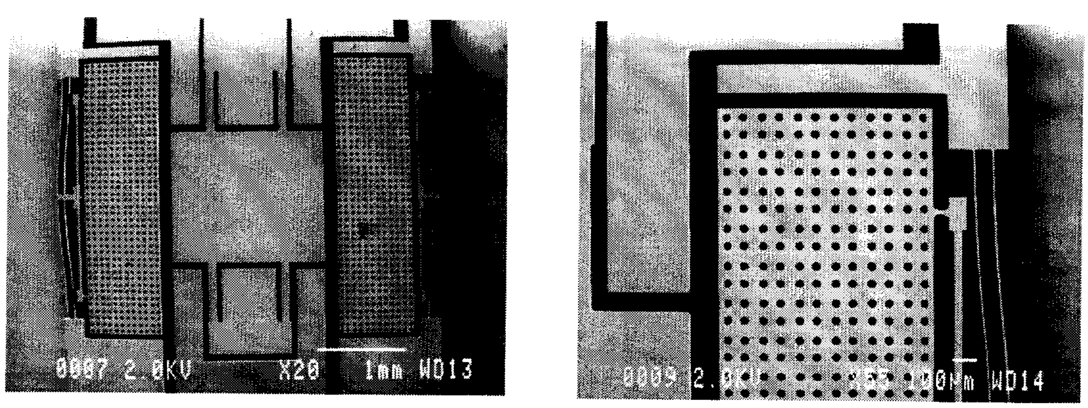

Fig. 3 The SEM photographs of a fabricated silicon structure.